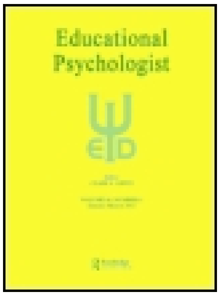
This article was downloaded by: [University of Cambridge]
On: 24 June 2013, At: 01:34
Publisher: Routledge
Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



Educational Psychologist
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/hedp20

The Social Brain, Language, and Goal-Directed Collective Thinking: A Social Conception of Cognition and Its Implications for Understanding How We Think, Teach, and Learn

Neil Mercer [a]

[a] Faculty of Education , University of Cambridge
Published online: 14 Jun 2013.

To cite this article: Neil Mercer (2013): The Social Brain, Language, and Goal-Directed Collective Thinking: A Social Conception of Cognition and Its Implications for Understanding How We Think, Teach, and Learn, Educational Psychologist, DOI:10.1080/00461520.2013.804394

To link to this article: http://dx.doi.org/10.1080/00461520.2013.804394

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: http://www.tandfonline.com/page/terms-and-conditions

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae, and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand, or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

EDUCATIONAL PSYCHOLOGIST, 1–21, 2013
Copyright © Division 15, American Psychological Association
ISSN: 0046-1520 print / 1532-6985 online
DOI: 10.1080/00461520.2013.804394

Routledge
Taylor & Francis Group

Downloaded by [University of Cambridge] at 01:34 24 June 2013

The Social Brain, Language, and Goal-Directed Collective Thinking: A Social Conception of Cognition and Its Implications for Understanding How We Think, Teach, and Learn

Neil Mercer
Faculty of Education
University of Cambridge

In recent years, researchers in evolutionary psychology and anthropology have proposed that the distinctive nature of human cognition is the product of our evolution as social beings; we are born with "social brains" that enable us to manage complex social relationships in ways other animals cannot. I suggest that the concept of the social brain is potentially useful for understanding the dynamic, iterative relationship between individual and collective thinking, and the role of language in mediating that relationship. However, I argue that its current conceptualization is too narrow and individualistic; the concept should be redefined to take account of the distinctive human capacity for thinking collectively. I suggest that Vygotskian sociocultural theory offers a framework for this reconceptualization, which would then enable us to achieve a better understanding of the relationship between "intermental" (collective) activity and "intramental" (individual) intellectual activity and development. I use this theoretical base to propose three explanations for the observed effects of collaborative learning on individual learning and development.

In 2010 the United Kingdom's Royal Society of Arts (RSA) organized a seminar entitled *The Social Brain and the Curriculum,* which brought together researchers from evolutionary psychology, neuroscience, computer-related studies, and educational research to share their views on this matter. One of the key issues that emerged was "The brain's sociality: The brain's constant orientation to others and the creation of meaning through brains interacting, rather than through the operation of individual internal cognition" (RSA, 2010, p. 2). In that seminar, the neuroscientist Frith took an evolutionary psychology stance to argue that the human brain is designed to enable people to adjust sensitively to one another's perspectives and emotions, so as to enable cooperative activity from which a whole community can benefit (see Wolpert & Frith, 2004). As a contributor to the seminar series, I was heartened to discover that neuroscientists and evolutionary psychologists were interested in social aspects of cognition and in addressing educationally relevant questions. However, the series did not allow any opportunity for the development of these ideas. For example, there were implications for how we could integrate different fields of study, and for how such a unified approach might address educational issues. One of my motivations for writing this article is to try to take these issues further.

The concept of the "social brain" was introduced by the evolutionary anthropologist Dunbar (1998) and has since generated some interesting and imaginative discussion about the relationship between individual mental capacities and social interaction. It represents the view that human intelligence has an intrinsically social quality, in that evolution has equipped us with brains that enable us to operate effectively in complex social networks. By linking cortical functioning, individual thinking, and social interaction, it seems to me that this concept could usefully bring together research in neuroscience, evolutionary psychology, developmental psychology, social psychology, and educational psychology, as well as connecting with other fields such as sociolinguistics and linguistic philosophy. However, I argue that if it is to fulfill that role, the social brain concept needs further development, because the social nature of human cognition has

Correspondence should be addressed to Neil Mercer, Faculty of Education, University of Cambridge, 184 Hills Road, Cambridge, CB2 8PQ, United Kingdom. E-mail: nmm31@cam.ac.uk

not been properly recognized in its development so far. The main focus of interest in the social brain has been on how individuals cope with the informational and emotional complexity of social life, so as to maximize the achievement of their personal goals. The concept has been strongly linked to evolutionary theory, but only through a narrow focus on the survival value for an individual of being able to understand the behavior and motives of others. No account has been taken of the potential survival value of a cognitive capacity for collaboration. Yet one reason why people engage socially, which can also be linked to human evolutionary success, is so that they can think collectively in order to pursue common goals. I suggest that our brains are "social" in that they have been designed, through evolution, to enable us to reason together and get things done.

Our evolved capacity for collective thinking also enables each new generation to benefit from the past experience of their community, which has given our species survival advantages over competitors. It is widely recognized by psychologists working in developmental and educational fields of enquiry that children learn to make sense of society and their environment by being engaged in dialogue by their carers, drawn into collective activities, and guided in ways of reasoning about experience. The potential capabilities of each child's social brain are developed through social interaction. However, this recognition does not seem to have permeated discussions of the social brain within cognitive and evolutionary psychology. The crucial role of language in such processes has also not yet been properly accommodated within those discussions. I propose a way that an evolutionary account of human origins can be linked to our understanding of the psychological mechanisms that underpin these aspects of human life, and in particular to the social and cognitive processes involved in education. To do so, a theoretical framework is needed for dealing with the relationship between collective thinking and the development of individual cognition—between the "intermental" and the "intramental"—and I suggest this could best be achieved by taking a sociocultural perspective based upon Vygotsky's work (Vygotsky, 1962, 1978). On this basis, I offer three possible explanations of how intermental activity might influence intramental development and then relate these to findings from several fields of research. A broader conception of the social brain emerges from this discussion, which has implications for future research in education and other fields, as I explain toward the end of the article. But first I consider how the concept of the social brain has emerged from research in evolutionary studies and neuroscience.

EVOLUTIONARY PSYCHOLOGY, NEUROSCIENCE, AND THE SOCIAL BRAIN

Researchers within the relatively new field of evolutionary psychology have striven to explain how the ways we think have shaped, and been shaped by, the struggle of our ancestors to survive and eventually become the dominant species. In early stages of its development, evolutionary psychology invoked a strongly individualistic notion of human cognition, explaining the origins and nature of human thinking in terms of the selective advantage individuals would gain over other individuals through thinking and behaving in certain ways, which would give them and their offspring a competitive advantage over others. The focus thus tended to be on competition between humans, with the success of the species as a whole being explained through the proportionally greater survival of the offspring of more successful individuals. Thus Miller (1999) argued that young men produce more "displays" of art, music, and other cultural products than women or older men because they are most highly motivated to compete for mates. At its crudest, as sometimes represented in the press or in media discussions, this approach might seem to be based on doubtful, analogical comparisons between the ways males of other species aggressively compete and the social behavior of men in modern society; but this would do a great disservice to the scholarly work in this field. However, evolutionary psychology has had a strong association with the kind of evolutionary account offered in Dawkins's (1976) book *The Selfish Gene*, whereby altruistic and collaborative behavior is expected to be limited to closely related individuals and interaction with nonrelatives is perceived as basically competitive. Thus one evolutionary psychologist writes, "It is not unreasonable to hypothesise that humans have evolved xenophobic fears of strangers and outgroup members" (Buss, 2001, p. 966). There have been philosophical criticisms of such highly individualistic, competitive applications of Darwinism (e.g., Midgeley, 2010), and recently within evolutionary psychology (and the closely related field of evolutionary anthropology) a recognition of the intrinsically complex nature of human social life, and the cognitive demands this makes of people, has begun to influence accounts of how and why the human brain has evolved in the way that it has. As I explain, some evolutionary scholars have begun to describe the distinctive nature of human cognition in terms of our ability to operate within complex social relationships. This links with other fields of psychological investigation, and not only with social psychology. For example, researchers in neuroscience claim to have identified features of neural function which show that we are sensitive, sometimes unconsciously, to very subtle "social signals" that enable us to respond to the intentional actions of others. This evidence has been used by some evolutionary psychologists (and anthropologists) to support their claims that the design of the human brain supports an inherently social function.

Dunbar (1998), a leading scholar in the field of evolutionary psychology/anthropology, has been prominent in setting out the case for the brain's "prosociality." He commented that the conventional wisdom over the past 160 years in cognitive psychology and neuroscience has been that the prime

Downloaded by [University of Cambridge] at 01:34 24 June 2013

Downloaded by [University of Cambridge] at 01:34 24 June 2013

function of the human brain is to enable individuals to process factual information about the world as effectively as possible. The unstated implication has been that the evolutionary struggle for survival would favor individuals with the best sensory, information-processing, and memorizing abilities. It is only relatively recently that it has been suggested that the nature and size of the human brain might also reflect the survival advantages of a more subtle kind of mental capacity, that of being able to make sense of complex social relationships. This has led evolutionary psychologists to propose that our brains have evolved to be able to perform specific "cognitive feats such as calculating the status trajectories of oneself and others in the group, and modeling the consequences of the injury or death of a kin member" (Buss, 2001, p. 968). New fields of research have since been defined ("social neuroscience" and even more specifically "developmental social cognitive neuroscience"; see Zelazo, Chandler, & Crone, 2009) to pursue this perspective. There has been a particular interest in how we notice and respond to the subtle social signals of people we interact with, even if we are not consciously aware of doing so. Research has identified "mirror neurons," which become active not only when a primate carries out an action but also when they observe a community member carrying out the same action. Most studies have involved monkeys, but recently neuroscientists have reported identifying the activity of mirror neurons in humans (Mukamel, Ekstrom, Kaplan, Iacoboni, & Fried, 2010). However, this "mirror" activity apparently arises only with the observation of *intentional* actions. It had already been well established by social psychologists that when people interact, they tend to reflect each other's gestures and postures (e.g., Chartrand & Bargh, 1999), and so this seems to offer a neural correlate for such findings. Commenting on the significance of this, Frith and Singer (2008) said, "Through the automatic activation of mirror systems when observing the movements of others, we tend to become aligned with them in terms of goals and actions" (p. 3875).

However, doubts have been expressed about the evolutionary account of the origins of mirror neurons in humans, for example by the psychologist Heyes (2010). She pointed to the lack of evidence that the human brain has single neurons that are biologically programmed to discharge when an action is performed or observed, and argued that rather than being "hard-wired" to respond in that way, the evidence reflects the effects of our associative learning, as we correlate the experiences of performing and observing the same actions. She cited studies which show that experience modifies mirror responses (so that, e.g., pianists respond more to observations of piano-playing finger movements than non-pianists), supporting that view. But whereas Heyes is unconvinced that hard-wired mirror neurons should be given a major role in the evolutionary development of the social brain, she conceded that her associative learning explanation of their origins is still compatible with mirror neurons having social-cognitive functions, which include understanding and predicting the actions of others, and language processing.

Even if mirror neurons are not hard-wired, it seems that our brains have been evolutionarily designed for living in a complex society. As Grist (2009) explained,

> We become aware of others because our brains can apply "theory of mind"—this is the cognitive endeavor of attributing thoughts to others. Part of theory of mind consists in thinking about what other people are thinking about other people—"what does Jane think about Tom's behavior towards Pablo, given that Pablo is upset about his father's illness?" This is a very complicated kind of cognition and is, as far as we know, unique to humans. The social brain hypothesis in evolutionary anthropology contends that human brains have evolved to be as big as they are so that we can think about and manage our relationships with other people. (p. 44)

The claims made by Grist and by Frith and Singer can be related not only to the well-established concept of theory of mind (Premack & Woodruff, 1978) but also to that of social cognition (as discussed, e.g., by Fiedler & Bless, 2001). The basic claim made by evolutionary anthropologists and psychologists is that advanced skills in social cognition—the ability to infer emotion and interpret social behavior—would be differentially selected for among our early ancestors. A species that possessed such skills would be more able to organize larger and more complex social groups. Individuals with the most developed skills within a community would have advantages in achieving their goals (including reproductive goals) because they could make sense of such social complexity (Dunbar, 1998) to help them compete with rivals (Buss, 2001) and so ensure that more of their offspring survived.

These discussions of social cognition by evolutionary psychologists represent a significant shift in perspective from the individual to the social. But they still tend to focus only on individual cognition and competition, rather than joint intellectual activity and collaboration. They also tend to describe the relevant skills as just being "there," inherent in the natural capabilities of the individual brain. From the perspective of an educational researcher, this seems simplistic and even inaccurate. Theory of mind can be considered a distinctive capacity within the broader notion of metacognition, in that it involves making assessments not only of one's own state of knowledge, intentions, and so on, but also of those of other people. Research in educational and developmental psychology suggests that, like other metacognitive and social skills, theory of mind develops through practice and guidance as children become involved in dialogues with other people, as I describe in a later section.

Downloaded by [University of Cambridge] at 01:34 24 June 2013

INDIVIDUAL AND COLLECTIVE THINKING

Making a link with evolutionary psychology, the linguistic philosophers Mercier and Sperber (2011) proposed that the human capacity for reasoning should primarily be understood as a competitive social mechanism, whereby we each strive to persuade others to comply with our preferred courses of action. Although this is interesting and plausible, it shares the weakness of the evolutionary psychology accounts just discussed by explaining human survival only in terms of individual people negotiating the social world and pursuing their own agendas. This may provide part of the explanation for the origins and nature of the cognitive capacity of our species, but it fails to acknowledge one of the most important functions of our social-cognitive capabilities, which is that we are able to engage together in goal-orientated, knowledge-building, and problem-solving activities. We do not only use reasoning as an individual weapon to resist other people's agendas; we also use it in dialogues to find the best possible solutions to the problems we jointly encounter. Frith and Singer (2008) hinted at this when they said, "When joint action requires cooperation, shared representations of task requirements and goals are very important in order to achieve better performance. Such sharing is referred to as *common knowledge*" (p. 3876).

The creation of "common knowledge" is an interactive, complex, discursive process, as educational research has shown (Edwards & Mercer, 1987/2012), and there is more to collective thinking than sharing knowledge. Theory of mind capabilities allow us not only to assess others' emotional states or try to exert a social influence on them: They also enable us to make assessments about what knowledge we have in common with another person, and judge their levels of understanding or skill in relation to particular topics or tasks. In ways that are just not possible for other species, we use interactions to continually refine our judgments of the relative states of knowledge and understanding of other people (Jeong & Chi, 2007). Both assessments of what others think and know and metacognitive reflections on our own thought processes are involved. These allow us to jointly activate the practical cycles of planning, acting, reflecting, and replanning by which we solve problems, share knowledge, and construct new joint understandings. Such mental capacity distinguishes us from other primates, as Tomasello (2008) explained:

> The great apes—chimpanzees, bonobos, gorillas and orangutans—communicate almost exclusively for the purpose of getting others to do what they want. Human infants, in addition, gesture and talk in order to share information with others–they want to be helpful. The free sharing of information also creates the possibility of pedagogy–in which adults impart information by telling and showing, and children trust and use this information with confidence. Our nearest primate relatives do not teach and learn in this manner. (p. 1)

One does not have to be convinced that "telling and showing" is a uniquely human behavior to accept that our species has developed it to unique levels of sophistication. Through becoming sensitive to the limits of one another's levels of understanding, we are especially able to engage effectively in interactions whereby one person helps another to learn. We differ from our primate relatives by having what Hermann, Call, Hernandez-Lloreda, Hare, and Tomasello (2007) called "cultural intelligence," by which they mean the ability to make sense of a complex, shifting social world and operate as a fully functioning member of it. Their comparative study found that young children (1 year old) "far outstripped" chimpanzees and orangutangs on tests of social cognition. But we have evolved the ability to do more than just make sense of a complex society and interact successfully within it. To an extent that is impossible for other primates, we are able to not merely interact but to "interthink" (Littleton & Mercer, 2013; Mercer, 2000). Through the use of language and other modes of representation, we can link our individual minds to create a powerful problem-solving tool. It is likely to be this, rather than individualized competition, that has ensured the dominance of our species. As an emergent species, our ancestors would compete well with other species because they could use language and other modes of representation to define common problems and plan in advance how to deal with them. They could also reflectively discuss the success or otherwise of those actions and plan again accordingly. By creating abstract representations of experience together, they could use them to explore the past and the future. Older members of a community could induct each new generation into their complex society's way of getting things done and share with them the insights of past collective thinking. Their children would learn ways of using language for representing the physical world and for reasoning about it. Collective intellectual activity thus would become to have a significant influence on the development of individual cognition. This perspective on the relationship between the social and the individual may seem obvious to educational and developmental psychologists, but it has not yet figured in discussions of the concept of the social brain.

Why has there been so little recognition of the importance, or even the existence, of collective thinking in evolutionary psychology? It may be because cognitive psychology has generally upheld the commonsense view that thinking just goes on in individuals' heads, and topics such as problem solving, learning and remembering have been studied accordingly. It is one of the most prestigious fields of psychological enquiry, and so it may simply be that this perspective has been carried over into evolutionary psychology. The study of collective thinking, which includes how people solve problems in groups or how one person helps another to learn, has been pursued quite separately by developmental, educational, and discursive psychologists (see, e.g., Cazden, 2001; Howe, 2010; Mercer & Littleton, 2007; Middleton & Edwards, 1990). Studies of how people think alone and how

Downloaded by [University of Cambridge] at 01:34 24 June 2013

they think together have never been united. I suggest that this division is an obstacle to developing a proper understanding of how humans think. Cognitive achievements and activities do not, of course, take place only in social settings, and I offer no arguments against the study of individual learning, remembering, or problem solving. But unless researchers recognize how the inherently social nature of our species shapes our cognition and its development, and the fact that we frequently learn, reason, and solve problems collectively, the accounts they generate will misrepresent how people actually think and learn in real life.

THE COGNITIVE FUNCTIONS OF LANGUAGE

Dunbar (1998) argued for the crucial role of language in the operation of the social brain as follows:

> For humans, one important aspect of [theory of mind] concerns its relevance to language, a communication medium that crucially depends on understanding interlocutors' mental states or intentions. The kinds of metaphorical uses of language that characterize not only our rather telegraphic everyday exchanges (in which "you know what I mean?" is a common terminal clause) but also lies at the very heart of the metaphorical features of language. (p. 189)

This is in accord with my own argument even if, once again, the focus is on the assessment of emotions and intentions, rather than on the collective representation of experience and the joint pursuit of solutions to problems. It could well be, as some have argued (Levinson, 2006), that our evolving capacity for reading the intentions of others underpinned the emergence of language; but this does not explain the significance of language as both a cognitive and cultural tool. Language is the prime means at our disposal for making a dynamic assessment of shared understanding and developing it, and so has a central, integrated position in enabling human cognition to be both individual and social:

> By participating in the conversations that accompany and grow out of the everyday activities in which he or she is involved together with other members of the culture, the child learns to use the semiotic tool of language, which enables him or her to "connect" with other people; at the same time, and by virtue of the mediating role that conversation plays in these activities, the child simultaneously "assimilates the experience of humankind", as this is encoded in the semantic system of that culture's language. (Wells, 1999, pp. 19–20)

There is more to this than humans using language to share information accurately, as some cognitive/evolutionary psychologists have claimed, such as Pinker (1994), when he said, "Simply by making noises with our mouths we can reliably cause precise new combinations of ideas to arise in each other's minds" (p. 15). Indeed we can pass on information to each other, and it is vital to human life that we do so. But as a generalization, Pinker's claim is patently false, as any teacher who has instructed a class of children on what to do will know when they all begin to do rather different things. Language's power as a tool for creative, collective thinking partly lies in the possibility that listeners may each interpret a speaker's words in rather different ways. Scholars are still interpreting the words of orators, philosophers, playwrights, and poets, hundreds of years after those words were expressed, and offering new insights into the human condition as a result. As Vygotsky's contemporary and compatriot, the literary scholar Bakhtin (1981), put it—or rather, as I interpret what he wrote—the words we hear or read do not simply activate a mental dictionary, they generate dialogic responses in our own minds as we use our existing knowledge to make sense of them. Vygotsky (1962) himself argued that language is both a cultural tool and a psychological tool, linking the "intermental" and the "intramental" in a reciprocal relationship, and so is inextricably bound up with the development and application of more advanced forms of reasoning. Thus Vass and Littleton (2010) suggested that "interpsychological thinking is a prerequisite for intrapsychological thinking: it is through speech and action with others that we learn to reason and gain individual consciousness" (p. 107).

The view that language is thoroughly integrated with other important nonlinguistic aspects of thinking is, of course, at odds with some influential views on language and cognition, notably of those who remain committed to a view of language as a discrete cognitive "module" or capacity (e.g., Pinker, 1994, 2007). But emerging findings from neuroscience support the more integrated view, as they suggest that mental abilities associated with some nonlinguistic skills, such as the appreciation of rhythmic patterns and structures in music, are also involved in language abilities. Thus Goswami (2009, p. 182), who has studied both linguistic and musical aspects of cognition, cited research (Abrams, Nicol, Zecker, & Kraus, 2008) on children's cortical responses to speech, which has shown that neural tracking of the "speech envelope" (the rhythmic, syllabic sequence of speech sounds) is accurately monitored by the right, not the left, hemisphere. Reviewing evidence from neuro-imaging research, Patel (2003) argued that syntactic features shared by music and language are processed by the same parts of the brain, and therefore that neuroscientists should no longer focus on language "in isolation."

We might also consider here research on bilingualism for what it tells us about the relationship between language and general cognitive functioning. Up to the middle of the 20th century, reviews of research tended to conclude that growing up bilingually causes some cognitive deficits, through some kind "overloading" of cognitive capacities (Darcy, 1963; Macnamara, 1966). In contrast, more recent research has shown that there are general cognitive benefits from growing up bilingual (Diaz, 1983; Grosjean, 2010). For example, it seems that bilingual children perform better in nonverbal

Downloaded by [University of Cambridge] at 01:34 24 June 2013

problem-solving tasks, which depend on selective attention or inhibitory control, as these controlling abilities have been enhanced through exercising linguistic choices between different languages (Bialystok & Feng, 2010). This advantage seems to continue throughout the bilingual's lifespan. The current view seems to be that bilingualism may offer both cognitive benefits and disadvantages. This is apparently also supported by evidence from neuro-imaging research (Bialystock et al., 2005). Bialystok and Feng (2010) offered this summary: "The picture emerging from these studies is a complex portrait of interactions between bilingualism and skill acquisition in which there are sometimes benefits for bilingual children, sometimes deficits, and sometimes no consequence at all" (p. 121). It is not of great significance to us here as to whether the effects of bilingualism on nonverbal reasoning are positive or negative: The key point is that this research indicates that language skills are integrated with nonverbal reasoning skills, and that language experience is linked to the development of those skills. As one bilingualism scholar wrote, "Language attributes are not separated in the cognitive system, but transfer readily and are interactive" (Baker, 2006, pp. 168–169). Evidence thus increasingly supports the view that language is involved with both specific and nonspecific aspects of brain function, and so is a fully integrated component of human cognition. If we want to understand the functioning of the social brain, in the broader sense of the term, and its development through childhood, I therefore suggest we need to recognize the crucial role that language plays in enabling us to think collectively and individually.

THE ROLE OF LANGUAGE IN DEVELOPMENT AND LEARNING

In recent years, one major influence on classroom research has been the emergence of a sociocultural theory of education and cognitive development derived from Vygotsky's work (as described, e.g., by Daniels, 2001, 2008; it is also known as cultural-historical activity theory: van Oers, Elbers, van der Veer, & Wardekker, 2008). Its basic premise is that human intelligence is essentially social and cultural, and that the relationship between social activity and individual thinking underpins cognitive development. As Vygotsky (1978) put it, "Human learning presupposes a specific social nature and a process by which children grow into the intellectual life of those around them" (p. 88). This has inspired empirical examinations of how social interaction influences individual learning, problem solving, and representations of knowledge. One leading sociocultural psychologist suggests that "all too often the focus of sociocultural research has been on *intermental* (social, interactional) processes *per se*, to the neglect of explanations of how these intermental processes forge the *intramental* processes that sit at the heart of cognitive development" (Rojas-Drummond, 2009, p. 241). My own view is that interest in intramental processes has tended to dominate; but in any case this theory's potential for making the link between social processes and individual thinking is there to be exploited. Sociocultural theory provides a theoretical basis for the primacy of language as a cultural and cognitive—and hence educational—tool. A model of the social brain in which language is a fully integrated component is compatible with two Vygotskian claims that (a) the development of individual psychological (intramental) functions is commonly preceded by involvement in related social (intermental) activity, and (b) the acquisition of language has a transformative effect on the nature of an individual's thinking. Sociocultural theory does not, as some of its critics have claimed, suggest that "everything that can be thought can be thought in language, and everything that can be represented, can be represented in language" (Jewitt, 2008, p. 7). There is no need to make any such extreme claims to justify a special focus on language, as I hope to show.

Empirically, it has been known for some time that the quality of children's language experience in the early years is a good predictor of their subsequent educational achievement (Hart & Risley, 1995; Wells, 1986, 2009). A good explanation for this involves children's induction into ways of using language for explaining and reasoning. Education is popularly understood as the transmission and acquisition of facts and skills, but educational success requires the ability to justify opinions, analyses, solutions, and conclusions. Although arguments can sometimes be presented through other communicative modes (such as the use of mathematical notation, and by physical demonstration in science or music), language is essentially involved in all academic subjects. Moreover, achieving competence in specific subjects requires the use of specialized discourses, or genres, of subject communities; and those genres are not mere jargon, but cultural tools designed for pursuing collective scholarship and enquiry (Christie & Martin, 1997; Kress, 1987; Swales, 1990). The linguist Martin (1993) described them as rule-governed, goal-orientated social processes embodied in language. They represent ways that individual thinking is made accountable to the normative rules of collective activity within specific communities of thinkers; and fluency in the appropriate genres is a requisite for full admission to those communities. Thus the educational researcher Pea (1993) argued, "*Expertise* is defined dynamically through continuing participation in the discourse of a community, not primarily through the possession of a set of problem-solving skills and conceptual structures" (p. 271). As Lemke (1990) famously put it, science education should enable students to become fluent speakers of science. The same principle applies in a great many nonacademic knowledge domains (Barton, 2009; Goodman, 1996; Lave & Wenger, 1991). Even if one is concerned with the development of understanding the content of a field of knowledge, rather than the manner in which it is expressed, language has a crucial role. In the debate about key factors in enabling students' conceptual change in science education, Treagust and Duit (2008a), leading

Downloaded by [University of Cambridge] at 01:34 24 June 2013

researchers in that field, have agreed with classroom researchers such as Wells (2008) that dialogue is commonly the "dynamic motor" for such change. Their own examples of transcribed dialogue (Treagust & Duit, 2008b) illustrate this well.

A sociocultural explanation of the role of language in individual and collective cognition can be based upon Vygotsky's proposed link between the intramental and the intermental. It begins with children learning and using the functional forms of language they hear around them. They practice these forms in "pretend play," acting out social roles such as "teacher" and "pupil" (Elbers, 1994). They "ventriloquate" the ways they hear adults making sense of the world as they try to make sense of the world themselves (Maybin, 2006). Those social modes of communication offer templates for individual sense making. If learning to participate in a subject like science involves learning to "speak" it, then learning to think like a scientist must involve some internalization of the subject discourse as a tool for reasoning about the relevant phenomena. Thus the genres of various discourse communities provide resources for organizing the process of individual thinking. One strength of Vygotsky's model, not always well appreciated, is that he envisaged the intermental–intramental relationship as enabling a kind of spiral intellectual development: Members of a new generation gain cultural understanding from their elders through the forms and content of dialogue, which then empowers them to make new, original insights, which are then shared and so enrich the culture of the community. It is through using the resources of specialized language genres that subjects, disciplines, trades, and other fields of human endeavor can persist and grow, within and across generations. In evolutionary terms, the emergent capacity to refine the tool of language into a diversified toolkit would offer adaptive advantages in dealing with changing environmental circumstances.

Understanding the role of language in children's intellectual development requires an analysis of how the intermental-intramental relationship is embodied in social interaction. The process whereby an expert guides a novice toward new understanding and competence is one of the basic, key features of human society; it is a manifestation of the powers of the social brain. It depends on the establishment and maintenance of an intersubjectivity that, at least in formal educational settings, is normally mediated through language. Instructing a learner, or providing useful feedback on their efforts, is very difficult without some kind of spoken or written dialogue. It is interesting and useful to highlight the multimodality of classroom education, by which gestures, nonlinguistic symbols, images, artifacts, and physical settings can also shape learning processes (e.g., Jewitt, Kress, Ogborn, & Tsartsarelis, 2004), but such analysis should not obscure the prime, central role of language.

Educational research on collaborative learning has mainly been motivated by an interest in if, and how, group-based learning activities help the learning and conceptual development of individual children (see, e.g., Howe, 2010; Slavin, 2009). I pursue that interest in the next section. But that is not the only reason for studying collaborative learning. We should recognize the importance of children learning to be good collaborative problem solvers. Understanding the role of language is vital for analyzing more symmetrical, collaborative types of learning and problem solving. In almost all joint problem-solving tasks it is impossible to collaborate properly without talking with a partner (or using the written "talk" of electronic communications). As the eminent classroom researcher Barnes (2010) put it,

> It is worth considering what is implied when, after someone has asked you to make a decision, you reply, "I'd like to talk it over first." It's not that you expect that the talk will give you new information. It's rather that you know from experience that the matter in question can often appear quite differently as a result of talking it through. The situation and its priorities and implications can take a different shape, a different meaning. You may see connections that were not immediately apparent, or realise that some of the options might have results that need to be considered. In that case, the talking is contributing to your understanding by reshaping what you already in a sense "know." This provides a useful model for the function of talk in learning, in that some kinds of talk contribute to understanding without necessarily adding new material. (p. 7)

THE INTERMENTAL AND THE INTRAMENTAL: EXPLAINING THE EFFECTS OF COLLECTIVE REASONING ON INDIVIDUAL REASONING

The distinctive quality of the social brain that has enabled the success of our species is, I have suggested, the capacity to link the intermental and the intramental. We have evolved to become able not only to make sense of complex social relations as individuals, but also to design and use those relations to create cognitive capability that transcends individual limitations. Moreover, we use collective cognition to enable the cognitive development of each new generation. This is the essence of the Vygotskian claim that social activity shapes psychological development. But the nature of that influence, regarding how elements of collective, social thinking affect subsequent individual thinking, has never been made clear (in Vygotsky's work or that of any other sociocultural theorist). This is a potentially very complex matter, and so for the sake of clarity I choose to approach it in the following way. First, I consider a specific aspect of cognitive development: the development of children's reasoning. Second, I consider how one kind of collective thinking, collaborative problem solving in the classroom, might stimulate the development of an individual child's reasoning capabilities. As I explain later, there is evidence that such joint activity can indeed, under certain conditions, have stimulating, beneficial effects—but for the moment, I am concerned only with elucidating the

Downloaded by [University of Cambridge] at 01:34 24 June 2013

hypothetical mechanisms for any such effects. I propose that there are three possible explanations, which might be called *appropriation*, *co-construction*, and *transformation*. I believe they are worth considering in some detail, because, although they are not mutually exclusive, they represent a series of relatively stronger theoretical claims about how language-based collaborative learning and problem solving might shape individual learning and development.

1. *Appropriation*: Children could learn successful problem-solving strategies and explanatory accounts from each other during joint activity. Through talking, they can share relevant knowledge effectively as they carry out a task, and explain their strategies to each other. They could thus acquire new, useful information and successful strategies for solving problems from each other and go on to apply them in any subsequent individual situation. This represents a relatively weak claim for the influence of joint activity on the development of individual thinking, because it merely identifies other people's explanations and demonstrations of knowledge and cognitive strategies as important resources for individual learning. Language plays an important role here, but only in so much as it is a medium for transmitting information with a fair degree of accuracy from one mind to another.
2. *Co-construction*: By using talk to coordinate their mental efforts, children could not only share ideas but also argue productively about them, to jointly construct new, robust, generalizable strategies together for completing a task that are better than any of them would have devised alone. Their improved group performance would reflect what has been called the "assembly bonus effect," whereby the performance of a group is better than that of its best member (Laughlin, Hatch, Silver, & Boh, 2006). Similarly, Woolley, Chabrsi, Pentland, Hashmi, and Malone (2010) invoked the notion of "collective intelligence" when reporting a study showing that the success of group endeavors is not strongly correlated with the average intelligence of group members but is correlated with the average social sensitivity of members and the equality in distribution of their conversational turn-taking. Individuals could then go on to use the new, effective strategies and solutions that the group had generated when faced with similar problems alone. This represents a stronger claim for the influence of social (intermental) activity on individual (intramental) learning and development because it locates the genesis of (at least some) effective cognitive strategies, understanding of problems and the generation of solutions in the dynamics of the "dialogic space" (Wegerif, 2007) of collaborative activity and not just in individual heads. Individuals in a group could also gain new levels of understanding through co-construction, through any explanations provided by their peers. "Co-construction" would also explain findings such as those of Smith et al. (2009), who reported that peer discussion among undergraduates enhanced their understanding of scientific concepts even when none of the individual participants initially had the requisite knowledge.
3. *Transformation*: The experience of group discussion could transform the nature of subsequent individual reasoning. If the norms of discussion required reasoning to be made explicit, and claims to be justified, the argumentation involved in collaborative problem solving might promote children's metacognitive, critical awareness of how they reasoned. Engaging in rational debate could also stimulate their theory of mind capacities, as they became more aware of the possibility of different points of view, of how these might be set against their own assumptions and of any contradictions generated. This would encourage a "reflective stance" and develop a capacity for intramental "dialogue" (Muller-Mirza & Perret-Clermont, 2009). This would help them to become more able to assess possible problem-solving strategies in a critical way, and to monitor and regulate their own problem solving when subsequently doing a task on their own. A child's thinking would thus be transformed, through intermental activity, so that they began to reason intramentally in a more "dialogic" way.

All three explanations are compatible with current versions of sociocultural theory. All three acknowledge, in different ways, the case for the special significance of language use in the development of reasoning. They all invoke the capacities of the social brain for sharing information, assessing common knowledge, and planning goal-directed activity—and for enabling useful knowledge and cognitive skills to be taken up among members of a community. As they are not mutually exclusive, all three explanations might be invoked to account for the effects of collaborative learning on individual learning and achievement. But although the "appropriation" explanation is quite prosaic, the "co-construction" and "transformation" explanations are not. "Co-construction" implies the exercise of some collective intelligence, which can achieve more than individuals can alone and which depends upon the quality of interaction. The "transformation" explanation is the most intriguing, because it embodies Vygotsky's claims about the transformative effects of social experience on psychological development, and of the key role of language in shaping individual cognition. It is also in accord with philosophical arguments offered by Wegerif (2010) and others that higher forms of human reasoning are essentially dialogic, meaning that the skilled thinker is able to take and consider different, even conflicting, viewpoints and debate them internally. It also could be related to the claims discussed earlier that reasoning functions best when set in argumentative contexts (Mercier & Sperber, 2011). But it links argumentation

Downloaded by [University of Cambridge] at 01:34 24 June 2013

with the success of collective endeavor and with individual cognitive development, in a way which purely competitive, individualized accounts of the functions of reasoning, like Mercier and Sperber's, cannot.

We might also consider if, and how, such explanations might relate to less socially symmetrical educational processes, such as when an adult helps a child, individually or as a member of a class, to learn or gain new understanding. The simplest explanation is again one of appropriation, whereby the adult simply shares relevant information with the child, provides instruction or demonstrates a strategy that the child acquires and uses. There would normally be no expectation here that the adult would gain a better understanding of the phenomenon under consideration, or would improve their level of skill in performing a task. But the process might nevertheless involve some form of co-construction, whereby the adult and the child generated a new, shared conception of the task in hand or the topic being studied. The adult might gain new insights into the learning task through becoming aware of the limits of understanding and misunderstandings of the child, whereas the child's understanding would converge on that of the adult. The interaction might also generate a new, clearer, and more explicit representation of the relevant knowledge, which was then shared by both teacher and learner. (It is a common experience for a teacher to find that teaching a topic to a learner who is struggling reveals the limits of their own understanding of it.) The child and adult would use language and other modes to establish intersubjectivity (in the sense used by Wertsch, 1979) and pursue the kind of goal-orientated, progressive, interactive process known as "scaffolded" learning (Bruner, 1983). Subsequently, the child could start to use a mental representation of the adult-led, scaffolded interaction in which they had been involved as a way of self-regulating their future individual activity. Their thinking would be transformed as a result. As I go on to show, this explanation has links with accounts of the development of children's ability to self-regulate their learning offered by developmental psychologists and educational researchers.

DIALOGUE AND THE DEVELOPMENT OF SELF-REGULATION AND METACOGNITION

Wertsch's (1979) seminal article on social interaction and higher mental processes made an important contribution by illustrating and explaining how the social regulation inherent in adult-child dialogues provides a model for the self-regulation of individual cognition. His transcribed examples of parent-child interaction provided the kind of empirical illustration that was lacking in Vygotsky's original account. Moreover, Wertsch went beyond the exposition of Vygotsky's ideas by offering an original model of four levels of interaction between an adult "teacher" and a child working together on a task, based on the quality of intersubjectivity attained by the participants. He showed how, at the fourth, most advanced level, a child began to use speech for self-regulation, which was similar in form and function to the speech used earlier by the adult when scaffolding the child's activities. He therefore provided evidence, underpinned by sociocultural theory, for how external regulation provides the resources for developing self-regulation. We know now that this process is not confined to preschool development. Children as old as 9 or 10 can be observed coregulating their group activity in class by invoking the earlier, authoritative instructions of the teacher (Warwick, Mercer, Kershner, & Kleine Staarman, 2010). Regarding individual development, research indicates that children's ability to regulate, monitor, and reflect upon their problem solving correlates strongly with their success as learners and problem solvers (Veenman & Spaans, 2005; Whitebread & Pino Pasternak, 2010). On the basis of meta-analyses of such research, some have claimed that the emergence of self-regulation is the main determinant of effective learning (Swanson, Hoskyn, & Lee, 1999; Wang, Haertel, &Walberg, 1990). The effects of dialogic experience on the development of the ability to self-regulate could thus be a crucial, transformative feature of cognitive development.

It has been widely observed that young children quite naturally talk aloud as they play alone, using language to regulate their solitary activities. Such "egocentric speech," as Piaget (1926) first described it, is normally no longer used when we grow older; not only because its use would be seen as a mark of eccentricity, but (if we follow Vygotsky rather than Piaget) because it has become internalized as the "silent speech" or "inner speech" of more mature cognition. The "transformation" explanation of the effects of dialogue on reasoning invokes a similar process to this process, whereby collective reasoning amongst peers, or scaffolded learning with an adult, acts as a template for the self-regulating mechanism of "inner speech," which is used in individual reasoning. As Clark (1998) put it,

> When the child, confronted by a tricky challenge, is "talked through" the problem by a more experienced agent, the child can often succeed at tasks which would otherwise prove impossible (think of learning to tie your shoelaces). Later on, when the adult is absent, the child can conduct a similar dialogue, but this time with herself. (p. 66)

Researchers have explored the ways that parents vary in how they use language to scaffold learning activities (e.g., Fidalgo & Pereira, 2005). Some have noted how parents of young children often use elaborative questions to guide discussions about shared experiences—and that such discussions seem to enhance children's abilities to recall those events (Reese, Haden, & Fivush, 1993). Observing how mothers and children (aged 30–42 months) discussed events they had previously experienced, Rudek and Haden (2005) noted that

> the "system" for talking about mental states seems . . . to be surprisingly well developed just as children enter a period

> in which there is marked changed in their understanding of mind. . . . The use of mental terms . . . during reminiscing may help to focus children's attention on mental processes such as thinking, believing, and knowing and encourage thought about memory and what it takes to remember. (pp. 543–544)

Reviews of research on the development of metacognitive and self-regulatory abilities by Dignath, Buettner, and Langfeldt (2008); Hattie, Biggs, and Purdie (1996); and Whitebread and Pino Pasternak (2010) conclude that such abilities can be significantly improved through adult guidance, which inevitably involves dialogue. Typically, those interventions that obtained significant improvements have involved making metacognitive and learning strategies explicit to children and encouraging them to reflect and talk about their learning. Several pedagogical techniques have been used to do so. Whitebread and Pino Pasternak summarized the main types as follows:

- "Co-operative group work" (Forman & Cazden, 1985): A range of techniques involving children in collaborative activities that oblige them to articulate their own understandings, evaluate their own performance, and be reflective about their own learning.
- "Self-explanations" (Siegler, 2002): An instructional practice that requires children to give "how" and "why" explanations about, for example, scientific phenomena or the events in a story and then asks children to give explanations of their own and an adult's reasoning.
- "Self-assessment" (Black & Wiliam, 1998): A range of pedagogical ideas involving children's self-assessment of their own learning, including, for example, children making their own choices about the level of difficulty of tasks to be undertaken and selecting their best work for reflective portfolios.
- "Debriefing" (Leat & Lin, 2003): A range of techniques for reflecting upon an activity or piece of learning including "encouraging pupils to ask questions," "making pupils explain themselves," and "communicating the purpose of lessons" (Whitebread & Pino Pasternak, 2010, p. 686).

Psychologists committed to an individualistic account of learning might see the success of these techniques as no more than evidence of effective instruction; in other words, they might feel it necessary only to invoke the appropriation explanation for children's learning to self-regulate. Techniques like "self-explanation" and "self-assessment" sound as if they are just things an individual does alone. But that would ignore the essentially interactive quality of those techniques, which involve conversations between experimenters/teachers and children which make demands on children's communicative and theory of mind capabilities. For example, a leading researcher on the educational value of self-explanations describes what is involved as follows:

> The particular form of self-explanation that we have examined involves asking children to explain the reasoning of another person. In particular, children are presented with a problem, they advance an answer, they are given feedback concerning the correct answer, and then the experimenter asks them, "How do you think I knew that?" (Siegler, 2002, pp. 38–39)

Siegler then went on to describe the effects on learning of this interactive, dialogic technique: "The results indicated that, as hypothesised, encouraging children to explain the reasoning underlying the experimenter's answer resulted in their learning more than feedback alone or feedback in combination with requests to explain their own reasoning" (Siegler, 2002, p. 40). Spoken dialogue has a crucial function in the practice of the other techniques too, with references by the researchers involved to children being encouraged to ask questions, give explanations, explain themselves to another person, and so on. One of the researchers responsible for the development of the self-assessment techniques included in the previous list has commented,

> The core activity of assessment for learning is the involvement of learners in formative dialogue, with their teachers, and with one another. Only through such activity can they become actively engaged in their own learning, and so acquire the confidence and skill needed to become effective learners. (Black, 2009, p. 5)

Researchers into seemingly individual activities such as metacognition and self-regulation increasingly recognize that cognitive processes can be embedded in social interaction, and that collective metacognitive activity enables individual metacognition. Terms like "socially-shared metacognition" (Iiskala, Vauras, Lehtinen, & Salonen, 2010) and "socially mediated metacognition" (Larkin, 2009) have been used by researchers to describe people reflecting together about problem-solving strategies and the outcomes of actions. Groups are described as using reasoned discussion to "co-regulate" their activities (Volet, Summers, & Thurman, 2009).

Moreover, research on metacognition and self-regulation provides some indirect support for the most radical, "transformation" explanation of how spoken dialogue can enable cognitive development. It seems that researchers consider the development of the individual ability to self-regulate a transformation in the quality of a child's thinking—a step change in the way they are able to learn and solve problems. Their research also supports the view that dialogue, of the right kind, enables this transformation. The important role of spoken language in that developmental process, though not always explicitly acknowledged in research on self-regulation, is also apparent. As I go on to explain, this provides us with a useful perspective for understanding the results of research on collaborative learning.

Downloaded by [University of Cambridge] at 01:34 24 June 2013

Downloaded by [University of Cambridge] at 01:34 24 June 2013

EDUCATING THE SOCIAL BRAIN: COLLABORATIVE LEARNING AND COGNITIVE DEVELOPMENT

Research on collaborative learning and problem solving has been an active field since the middle of the last century. Interventional methods have commonly been used to try to improve social relations or communications among students and see if this improves the quality of collaborative learning, and hence learning outcomes. Most research has involved children, but some studies have been carried out with adults. As previously mentioned, most of that research has also been concerned with the effects of collaborative learning on individual learning and development, rather than on the development of collaborative problem-solving skills. It has been found, for example, that experience of group-based reasoning activities improves subsequent individual performance of reasoning on a task (e.g., Augustinova, 2008). School-based studies have provided convincing evidence for the educational value of collaborative learning. Roseth, Johnson, and Johnson's (2008) meta-analytic review of 148 studies involving students aged 11 to 15 concluded that cooperative learning has positive effects on academic achievement, with Slavin's (2009) review drawing similar conclusions.

We also know that some particular features of the talk between collaborating partners are associated with good individual learning outcomes. Howe (2009, 2010) described a series of related studies on collaborative learning in science education. For example, in pairs, 8-year-olds were asked to predict whether an empty metal box, or a solid rubber ring, would float in a tank of water. Having talked about this and agreed on a prediction, they would then test this with real objects. The children were pre- and posttested (immediately after the task, and after a substantial delay of some weeks) on their understanding of the relevant phenomena. It was found that significantly better results on delayed posttests of learning and understanding were obtained when groups of children (a) were asked to seek agreement on their predictions before testing them (even if they did not achieve agreement) and (b) worked in a group in which contrasting opinions were expressed. Moreover, it did not seem to matter whether agreement was actually reached, or if contrasting views were reconciled. What was important was that "seeking agreement" and "contrasting opinions" were features of the discussions. In explaining these results, Howe suggested that (a) having to seek agreement encourages children to pursue their discussions in more depth and to more certain conclusions and (b) unresolved contradiction between ideas during conversation particularly primes children's metacognition—with the result that they subsequently reflect more on what they think about the phenomenon, and on the significance of their observations. This is in accord with the results of some studies involving adult participants, which found that the generation of debate was a requirement for group activities to lead to improved performance on reasoning tasks: see, for example, Schulz-Hardt, Brodbeck, Mojzisch, Kerschreiter, and Frey (2006).

Other research has suggested that for dialogue in problem-solving groups to be productive (in terms of assisting problem solving, learning, and the development of understanding), it should have the characteristics of what my colleagues and I have called Exploratory Talk (a term originally used by Barnes, 1976; see also Barnes, 2008). Exploratory Talk is dialogue in which

> partners engage critically but constructively with each other's ideas. Statements and suggestions are offered for joint consideration. These may be challenged and counter-challenged, but challenges are justified and alternative hypotheses are offered. Partners all actively participate, and opinions are sought and considered before decisions are jointly made. (Mercer & Littleton, 2007, p. 59)

It represents language being used not just to distribute information among people (cf. Pinker, 1994) but being employed as a *social mode of reasoning*. Others have used the terms "transactive dialogue" (Berkowitz, Gibbs, & Broughton, 1980) and "accountable talk" (Keefer, Zeitz, & Resnick, 2000; Michaels & O'Connor, 2002) to describe similar ways of using talk effectively for collective reasoning. As Howe (2010) commented, research on collaborative learning does "not merely confirm that . . . transactive dialogue, exploratory talk, or whatever can precipitate growth; it also shows that these forms of social interaction are so powerful that they can sustain cognitive activity over many weeks" (p. 80).

The value of collaborative, group-based activity in the classroom has been clearly demonstrated, in relation to the study of various curriculum subjects (see also Mercer & Sams, 2006; Sfard, 2001; Slavin, Groff, & Lake, 2009). But research on classroom-based group work embodies a paradox: It has shown the value of collaborative learning, but it has also shown that much of the group activity which goes on in classrooms has little educational value. The relevant research was mainly carried out some time ago (e.g., Bennett & Cass, 1989; Wegerif & Scrimshaw, 1997), but no evidence has been offered more recently to suggest that the situation has improved significantly. Moreover, a recent meta-analysis of collaborative learning approaches for developing reading skills concludes

> that not all discussion approaches are created equal, nor are they equally powerful at increasing students' high-level comprehension of text. . . . It is one thing to get students to talk to each other during literacy instruction but quite another to ensure that such engagement translates into significant learning. (Murphy, Wilkinson, Soter, Hennessy, & Alexander, 2009, p. 761)

This paradox can be resolved, fortunately, by distinguishing between what normally happens and what could, or should, happen. The ability to think collectively may be an important

Downloaded by [University of Cambridge] at 01:34 24 June 2013

and defining characteristic of our species, but that does not mean that children are born knowing how to do it well. To make the most of collaborative learning activities, it is necessary for partners to use their social brains and the cultural and psychological tool of spoken language to best effect. Some educational research has studied the effects of training children in the use of language as a tool for collective reasoning, as I go on to describe in the next section. That research will also provide a useful basis for further consideration of the three explanations (appropriation, co-construction, and transformation) of how *inter*amental activity can assist *intra*mental development.

INTEGRATING TEACHER-STUDENT TALK WITH COLLABORATIVE LEARNING

A study of teachers in Mexican classrooms (Rojas-Drummond, Mercer, & Dabrowski, 2001) found that those whose students achieved the best learning outcomes (as represented by assessments of their progress in mathematics and literacy) not only avoided the dominance of closed questions but also organized more interchanges of ideas and mutual support amongst pupils and generally encouraged pupils to take a more active, vocal role in classroom events than the less effective teachers. That is, they enacted a sociocultural, "dialogic" model of education, even though they did not necessarily describe it as such. More large-scale studies are needed to test the value of a dialogic pedagogy (Rezniyskaya & Gregory, 2013). But overall, the available evidence supports those researchers who have argued for a more dialogic classroom pedagogy in which students have opportunities to express their understandings and misunderstanding, think aloud, ask questions, and explore ideas without being immediately evaluated as "wrong" or "right" by the teacher (Alexander, 2001, 2008; Dawes, 2008; Mercer, 1995; Nystrand, 1997; Skidmore, 2006; Scott, 2008; Wells, 1999, 2009). It seems, therefore, that classroom education should provide opportunities for students to think collectively, co-constructing knowledge and understanding and solving problems collectively. But if group work is to be productive, teachers also need to scaffold the development of students' intramental capabilities. As the science education researcher Black (2009) commented,

> By listening carefully to what others say, by giving emphasis to reasoned understanding rather than to formulaic answers, and by trying to help the class to arrive at consensus in a shared understanding rather than by imposing a conclusion arbitrarily, a teacher can make whole-class dialogue a model for pupils' group discussions. In both contexts, pupils are experiencing engagement in reasoned discourse. (p. 4)

Black's comments are supported by empirical research. In their review of mathematics teaching, Walshaw and Anthony (2008) concluded that "classroom work is made more enriching when discussion involves the co-construction of mathematical knowledge through the respectful exchange of ideas" (p. 543). Webb, Nemer, and Ing (2006) reported that differences between teachers in the extent to which they asked students to elaborate their problem-solving strategies corresponded strongly to the extent to which students did so during group discussions. Their general conclusion is that one of the main influences on children's talk in groups is the kind of talk that their teacher uses in interactions with them; but that teachers may not often model effective discussion in whole-class sessions. Yet children may not have many opportunities to learn how to conduct reasoned discussions in their out-of-school lives, or may not realize that they should engage in them when given collaborative tasks in the classroom. If their teachers do not raise their awareness of how they might talk and work together, or provide them with models and guidance, they are unlikely to develop the relevant skills for collective thinking and apply them appropriately. It is not so surprising, then, that in peer group discussions the talk is often off-topic, unproductively disputational and inequitable. Children may all have inherited the capabilities of the social brain, but like most human capabilities they require exercise and training.

Some interventional research has studied the effects of teachers guiding students in "collaborative reasoning." For example, Retznitkaya et al.'s (2001) study involved students aged 10 to 11 years, constituting three classes that participated in teacher-led collaborative reasoning discussions of literary texts for a period of 5 weeks. These students and students from three comparable classrooms, who had not engaged in collaborative reasoning, were asked to write persuasive essays. The essays of the intervention class students were found to contain a significantly greater number of relevant arguments, counterarguments, rebuttals, formal argument devices, and uses of text information. Through analyzing the talk during such interventions, in which a teacher modeled and guided discussions of that kind about literary texts, Chinn, Anderson, and Waggoner (2001) concluded,

> Four cognitive processes integral to good thinking and greater learning were found more frequently in Collaborative Reasoning discussions than in Recitations [i.e. those based on the traditional 'closed question' type of interaction]. In comparison with students in Recitations, students in Collaborative Reasoning discussions (a) made many more elaborations, (b) made many more predictions, (c) provided evidence at a rate nearly 10 times higher than in Recitations, and (d) were much more likely to articulate alternative perspectives. (p. 398)

A rather different illustration of how whole-class and group work activities can be integrated is provided by research involving a revision method called *prescriptive tutoring* (Soong & Mercer, 2011). Its aim was to reveal secondary school students' misconceptions and misunderstandings in physics by

Downloaded by [University of Cambridge] at 01:34 24 June 2013

getting them to solve physics problems with a partner in their class. However, the partners collaborated only through computer-mediated communication, and their dialogue was saved as text. Before they began to work together online, the students were encouraged by their teacher to agree on a set of "ground rules" for making their discussions suitably rational, explicit, and equitable. (The rationale for this is explained in more detail next, in relation to the Thinking Together research.) These ground rules stated that the students would agree to

- share their ideas and listen to each other;
- consider what their partner(s) has written or drawn;
- respect each other's opinions;
- give reasons for their ideas;
- express their ideas and workings neatly and clearly;
- in the case of disagreement, ask "why?" or provide reasons for their disagreement;
- only work on solving the problems (e.g., no web-surfing);
- try to concur on a solution, prior to asking the teacher to check their answer.

By agreement with the students, their teacher was allowed to read their online dialogues and use them as a basis for subsequent whole-class discussions. Implemented and evaluated in a public secondary school in Singapore, the results of prescriptive tutoring showed that students in the experimental group significantly outperformed students in a matched control group on postintervention tests of understanding of physics concepts.

Some researchers have tried to ensure that collaborative learning is more effective by encouraging teachers to use whole-class sessions to guide and model children's use of language for reasoning. The Thinking Together intervention studies carried out by myself and colleagues have so far involved more than 700 children, aged 6 to 14. These studies have been described in detail elsewhere (e.g., Mercer & Littleton, 2007), so I summarize here only those aspects relevant to my argument. Essentially, each class agrees to follow a set of "ground rules" for talking together in groups, which early studies showed help to generate more Exploratory Talk. Students are then expected to apply these rules during all curriculum-related group work, and the teacher uses whole-class sessions to model Exploratory Talk and encourage children's meta-awareness of the ways they use language for reasoning (Dawes, 2012).

Compared with control classes following their normal course of study, results have shown that children who follow the Thinking Together intervention program begin to use much more Exploratory Talk and pursue group activities more cooperatively. One study with children aged 9 and 10 found that they also gained significantly higher scores in national, curriculum-based tests of science and mathematics (Mercer, Dawes, Wegerif, & Sams, 2004). Moreover—and crucially for the case I am making here—the children in the interventional classes became significantly better at reasoning, as assessed by the Raven's Progressive Matrices test (Raven, Court, & Raven, 1995) both collectively and alone. Before the intervention, children in both control and experimental classes were given the Raven's test twice: once in groups and once (using a different version of the test) on their own, in that order. After the intervention, they all again did the test in groups and as individuals. The intervention children obtained better group *and* individual scores on the postintervention collaborative application of the test than the control children (although the intervention children had no more opportunities to practice the Raven's problems than the control children). It seems that they had learned not only how to "interthink" more effectively but also how to reason better on their own. These results have been replicated in Mexican schools (Rojas-Drummond & Mercer, 2004).

These results can be related to the three explanations of how intermental activity influences intramental learning and development I offered earlier. I consider each in turn, regarding how they might explain the greater success of the children in the experimental groups in the postintervention, group-based, and individual Raven's tests.

Appropriation. The relative success of the experimental children in the postintervention group-based Raven's test must depend on those children applying better problem-solving strategies than those in control classes. It is unlikely that more individual children in the experimental classes came along with effective strategies already in place than those in the control classes, so greater success in the *group* test would depend on the experimental children being better than control children at sharing and making use of any effective strategies that individual members already knew, or devised on the spot, in this one session. An appropriation explanation of the relatively greater success of the experimental children in the *individual* tests would thus depend on a significant number of them having learned better strategies from each other in that one group session.

Co-construction. The greater success of the experimental children in the postintervention group test could result from individual children in the experimental groups being more able than control class children to combine and apply their relevant knowledge and insights to the task, and so construct effective new strategies for solving the Raven's problems than they would have done alone. On the basis of their training and practice in Exploratory Talk, they would do this through a process of reasoned argumentation, whereby any suggestions made by group members would be critically evaluated and any resultant successful strategies constructed would be learned and subsequently applied by individual members when working alone. Their relative success as individuals thus would depend crucially on them being more able than children in the control classes to construct new

Downloaded by [University of Cambridge] at 01:34 24 June 2013

strategies in the one postintervention group session and then use them in the individual session.

We can see a group of children engaging in the kind of co-constructive approach to solving a Raven's problem that would accord with this explanation in Sequence 1, which comes from an experimental class in a study carried out in Mexican schools. As the sequence begins, the children (aged 12) are trying to decide which one of a possible set of patterns would logically complete an unfinished sequence of patterns made up of features that the children refer to as dots, crosses, and stars.

Sequence 1: Georgina, Luis and Mauro doing Raven's test item E5

Georgina:	Here they remove the dots and this, this cross *(points at a drawing)*
Mauro:	No but wait, it does not fit
Luis:	No, wait
Mauro:	No
Georgina:	Let's look at the sequence. Here it is like this, they remove the cross and the dots. Here they are not there any more, here *(points)*
Luis:	And here they remove only the dots
Georgina:	Yes, the dots. And this part, only the star
Mauro:	It would be this one, look at it *(points)*
Luis:	Which they have removed
Mauro:	It would be this one, because, look, it goes like this *(points)*
Georgina:	But how, if it doesn't have dots?
Luis:	It doesn't have dots. Just the cross would remain
Georgina:	Yeah, because they have been removed!

(Georgina writes down option number 1 on the answer sheet, which is correct)

(Adapted from Rojas-Drummond & Mercer, 2004, p. 109)

Some aspects of their reasoning may not be clear to a reader, because they sometimes (and appropriately enough) rely on pointing to a pattern to support their arguments; but the discussion nevertheless has many features of Exploratory Talk with its challenges, reasoned justifications, and equitable distribution of conversational turns. Together, they construct and employ a mental scenario in which the originators of the test have differentially "removed" certain features from specific patterns in the series, leading to the logical inevitability of one of the possible solutions being correct. From reading the sequence, it would be difficult to attribute the group's success to the contributions of any one member.

Transformation. Their teachers' modeling of Exploratory Talk and establishment of "ground rules" for discussion would enable the experimental children to solve problems more effectively in the group tests, because they would use that experience of external regulation to coregulate their activities. This would make them more effective at sharing knowledge and co-constructing an explanation, as previously suggested. But that external regulation, and their practice in using Exploratory Talk as a group, would also act as a template for self-regulation and reasoning when they tackled problems alone in the *individual* tests. That is, Exploratory Talk would act as a template for carrying out the "inner dialogue" of individual reasoning. In the postintervention individual sessions, the relative success of the experimental children would thus not necessarily depend on their retention and employment of useful strategies co-constructed in the group session. It could also be assisted by their enhanced ability to reason "dialogically" about *any* problems they were given. They would engage in any new problem-solving task in a more metacognitive, self-regulatory way. This would make it more likely that they achieved correct solutions, as they would be more able to generate and apply good strategies for themselves and not only recall them from the previous group session.

According to the "transformation" explanation, then, the success of the Thinking Together intervention would depend on it having enabled children not only become more able to have reasoned discussions with peers but also become more able to have a "reasoned discussion" on their own. This represents a very strong claim for the effects of social activity on individual cognition, because it explains the development of a sophisticated, educated manner of individual thinking through the internalization of collective reasoning. The cognition of a normally developing child would not only be "social" because the human brain has inherent sensitivities to the signaled intentions and emotions of others (as argued by evolutionary psychologists), but because it embodies a way of thinking that takes account of the possibility of multiple, varied perspectives and explanations which need to be compared and evaluated. We might note here that, in research discussed earlier, Howe (2009) found that the incidence of unresolved contradictions or disagreements during children's collaborative problem-solving science tasks had a positive correlation with scores on *delayed* posttests of children's scientific understanding but not on *immediate* posttests. Those findings suggest that even if the coconstruction of a satisfactory explanation is not achieved during collaboration, the kind of intermental activity which takes place during Exploratory Talk may stimulate subsequent intramental "dialogue," which enables the individual to achieve a new level of understanding.

Are there reasons for believing that the "transformation" explanation applies to the results of the Thinking Together interventions: that the intervention children's "monological" reasoning became more "dialogic" through some kind of internalization of their Exploratory Talk? There are, though only to a limited extent. We have evidence that intervention class children went on to deal more successfully as individuals than control class children with new types of reasoning problems and provided better written arguments

Downloaded by [University of Cambridge] at 01:34 24 June 2013

to support their arguments in English assessments (Mercer & Littleton, 2007, Chapter 6). "Transformation" would also account for intervention children's subsequently improved performances when dealing with new mathematics, science, and English assignments involving reasoning which they had not practiced with their peers—they could apply to them an improved general reasoning skill that involved thinking dialogically. There is also some anecdotal evidence from teachers participating in the Thinking Together research that they observed that children were able to reason more effectively (in speech and writing) about new topics after the intervention. However, the Thinking Together studies preceded the formulation of the three explanations of effect, and so were not designed to discriminate between them. Perhaps, as sociocultural researcher Futoshi Hiruma (personal communication, May 12, 2008) suggested, in any new studies children from intervention and control classes should be asked to "think aloud" as they deal individually with new types of problem-solving tasks, to test the hypothesis that the intervention children would offer more explicitly reasoned protocols that were related to the structure and content of the classroom dialogues in which they had been involved. This might be combined with Howe's (2009) methodology of immediate and delayed posttests of children's understanding after collaborative work—which could include their developing understanding of how they use talk for thinking together and/or how they reason alone. The use of sociocultural discourse analysis (Mercer, 2008, 2009), with its methods for tracking the temporal trajectory of talk through time, and hence the appropriation by children of linguistic items and structures from their earlier experiences, would be appropriate here. This would tell us more about if, and how, dialogue can transform the quality of individual reasoning.

A related possible line of inquiry would build stronger links between research on dialogue and that on the development of metacognition and self-regulation. My colleagues[1] and I have already designed and tested an intervention program on that basis, for use by Year 1 teachers with their classes. Essentially, it requires teachers to use the Thinking Together approach to raise children's awareness and skills in working and talking together, and then engage them in a series of collaborative problem-solving tasks that require collective reasoning. This program has so far been tested in a pilot study (the Children Articulating Thinking [ChAT] Project) involving six primary school teachers and their classes. The main hypothesis has been that developing the children's use of language as a tool for social, joint regulation in problem solving will stimulate the development of their individual self-regulation and metacognitive abilities—and that this will be demonstrated through comparisons with children in control classes when they subsequently attempt individual tasks. The results (unpublished as yet) are encouraging, with children in intervention classes becoming better at discussing problems together and coregulating their activity. They improved significantly more than control classes on measures of conceptual understanding, quality of reasoning and metacognition on a music task. They were also able to explain their reasoning to a researcher more explicitly when doing both a music-related and a science-related task (concerned with floating and sinking). We have also tested for any improvements in children's performance on a problem-solving task where they had to assemble a model railway track to a given template (adapted from Karmiloff-Smith, 1979), but results of that are not yet available. A larger study, involving a modified intervention program, is being planned.

[1]David Whitebread, Deborah Pino-Pasternak, Christine Howe, Jane Warwick, Penny Coltman, and Usha Goswami.

DOES COLLABORATION HELP TO SOLVE PROBLEMS?

I have offered evidence in support of the value of collective intellectual activity for the development of children's reasoning. But my argument early in this article for the evolutionary importance of the emergence of a capacity for thinking collectively also requires evidence to show that, at least in some situations, collective thinking is more productive and effective than solitary thinking. One source is from studies of pairs and teams of adults working together. These range from quasi-experimental studies (as reviewed in Nemeth, 1995; Paulus, Dzindolet, & Kohn, 2012) to more ethnographic accounts (Miell & Littleton, 2008) and biographical case studies (John-Steiner, 2000). I mentioned earlier the assembly bonus effect, discovered by some researchers, whereby the performance of a group is better than that of its best member (Laughlin et al., 2006); and that although the success of group endeavors does not correlate strongly with the average intelligence of group members, it is correlated with the average social sensitivity of members and the equality in distribution of their conversational turn-taking (Woolley et al., 2010). Biographical case studies strongly encourage the view that some of the most significant and creative human achievements can be explained only through the joint activity of more than one talented individual, with conversational interaction between collaborators being seen as important. Psychological research on creativity has correspondingly begun to widen its focus from understanding the talents of gifted individuals to include studies of how people are collectively creative. Several studies take a sociocultural theoretical perspective, in which culturally framed ways of communicating and the use of cultural tools are considered important (Miell & Littleton, 2004; Paulus & Nijstad, 2003; Sawyer, 2012; Sawyer & DeZutter, 2009). In a meta-review of research on "orchestrating creativity," Hämäläinen and Vähäsantane (2011) noted that within recent studies of collaborative creativity, "the different roles of group members, including mutual explaining and shared knowledge construction, have been seen to enable new creative processes and outputs" (p. 172).

Downloaded by [University of Cambridge] at 01:34 24 June 2013

Some researchers have begun to offer "co-construction" explanations of creativity, even sometimes using that term (Rojas-Drummond, Mazon, Fernandez, & Wegerif, 2006).

However, reviewing experimental studies into group-based work activity, one team of experienced researchers has commented, "We do not know of a study that has clearly demonstrated . . . enhanced performance of teamwork relative to working as individuals" (Paulus et al., 2012, p. 348). Some research has highlighted the flaws in collective thinking processes, as when "groupthink" leads to unjustifiable consensus (Baron, 2005; Janis, 1982). Surprisingly, too, there seem to have been few detailed studies of how the use of talk in noneducational working groups leads to effective creative and outcomes (though see Edwards & Middleton, 1986; Middup, Coughlan, & Johnson, 2010; Miell & Littleton, 2008). Nevertheless, extrapolating from the available evidence to connect with my theme here, it is possible to draw some conclusions. The most reasonable answer to the question, "Do people solve problems more effectively when working together than alone?" is "In the right circumstances, yes." It depends to some extent on the nature of the task, and on the quality of the interactions within a group. As in studies of collaborative learning in educational settings, working teams have been found to achieve better solutions than individuals, and sometimes very significantly so, but only if they communicate effectively. For example, "groupthink" can be avoided by following ground rules that encourage reasonable dissent (Nemeth, 1995). Relevant research supports the view that the success of working teams depends on members using, when appropriate, a mode of interaction which resembles Exploratory Talk (Littleton & Mercer, 2013). Yet, as in the classroom, problem-solving discussions in the workplace are often not of this kind. As mentioned earlier, in evolutionary anthropology and psychology it tends to be assumed that the skills of social cognition are "hard-wired" and ready to use. But, like educational research, research in this field encourages the view that although people inherit a distinctively human capacity for thinking socially and collectively, these skills need to be developed and practiced.

CONCLUSIONS

In this article, I have suggested that the concept of the social brain could help to integrate research in evolutionary psychology, developmental psychology, social psychology, educational psychology, and other fields such as linguistics and philosophy, generating a better account of the distinctive nature of human cognition. The origin of the concept lies in evolutionary studies of human behavior, and that lively field of inquiry offers a fresh perspective that should not be ignored in more established fields of psychological and educational research. But I suggest that we should question its evolutionary account of our origins, which is predicated principally upon competition between individuals. I have argued instead that our evolution has equipped us with the distinctive human capability for engaging in goal-orientated collective thinking, so that we are able to achieve more together than we each could do alone. I have therefore proposed that the concept of the social brain should be developed beyond its initial definition, which is concerned with how humans interpret and negotiate complex social relations to pursue their individualistic needs. The sociality of the brain does not just enable each of us to cope with the complexity of society and pursue our own agendas, it also enables us to solve problems together and to create and develop knowledge at the cultural level. Although collective intellectual activity is not always more creative and productive than individual efforts, research has shown that it has the kinds of distinctive functions and benefits which support my argument.

Research in several fields provides additional support for an expanded conception of the social brain, as I have shown. The special human capacity for "theory of mind" allows us to appreciate that we each may have different perspectives and concerns, and motivates us to assess and monitor one another's states of understanding and common knowledge. This provides a basis for educating each new generation, as intermental activity allows more experienced members of a community to have a formative influence on the intramental development of less experienced members. I have used findings from several lines of inquiry to argue that the process of reasoning collectively, which has been crucial for the success of our species, provides a template for the development of individual reasoning. The distinctive nature of the social brain, then, is encapsulated in the relationship between the intermental and the intramental, the social and the psychological. Language, which has evolved in conjunction with the social brain, has a special role in mediating that relationship, through its integration with cognition generally and its use as both a cultural/social and psychological tool (or, rather, toolkit). I have offered three explanations of the effects of collaborative learning and dialogue on the development of children's reasoning—*appropriation*, *co-construction*, and *transformation*. They stand as potentially complementary, rather than as alternative, explanations. Individualistic accounts of reasoning and its development are inadequate in comparison because they struggle to explain both the "assembly bonus effects" of collective intellectual activity and the ways that educated modes of individual thinking embody essential features of reasoned dialogue.

Through creating links between evolutionary, social, developmental, and educational psychology, the expanded concept of the social brain could strengthen a sociocultural account of human learning and cognitive development and might also help neuroscience research and educational research become better integrated. The direct relevance and value of the findings of neuroscience for improving educational practice and theory have been recognized to be limited so far, even by those involved (Goswami, 2007). Most neuroscience research has been aimed at explaining brain function,

Downloaded by [University of Cambridge] at 01:34 24 June 2013

not addressing educational concerns (Willingham, 2009). Moreover, when educational issues have been addressed by neuroscientists there has been a narrow focus on how research might serve the perceived needs of practitioners, and how to make the findings of neuroscience intelligible to teachers, rather than how neuroscientists could collaborate with psychologists of education or other researchers in investigating educational research questions (Mason, 2009). For example, if neuroscience could begin to identify the ways in which language functions are related to, or integrated with, more general processes of learning or problem solving, it might help explain why children's early language experience can so profoundly affect the course of their intellectual and academic development. Could neuroscientists also contribute to our understanding of such processes by studying how brains operate in conjunction: for example, how spoken dialogue is reflected in the brain functioning of partners? Or could they investigate whether the exercise of "theory of mind" capacities, the establishment of common knowledge, and the formulation of joint plans of action, involve "mirrored" neural activity in the brains of partners engaged in joint problem solving? More adventurously, we might hope for studies that investigate ways that the brain activity of teachers and students, or collaborating learners, are correlated during joint activity. By combining the methods of neuroscience with those of discourse analysis, we might even seek the correlates of Exploratory Talk. And if neuroscience research provided more evidence that language use is indeed a wholly integrated aspect of brain function, this might encourage more educational and psychological researchers to investigate the role of language in learning and conceptual development, and specifically in the development of metacognition and self-regulation.

A reviewer of this article in draft suggested that it would be better directed at an audience of evolutionary psychologists and neuroscientists, rather than psychologists of education who commonly take a sociocultural perspective and so do not need to be persuaded of its value or of the need to study processes of collaborative learning. But the focus of most research on collaborative learning has been on the effects of joint intellectual activity on individual learning and development, rather than on understanding and improving collaborative problem solving in its own right. This suggests that researchers in that field may be, ironically, trapped in a similar kind of individualistic perspective to those in evolutionary and cognitive psychology. The ability to think collectively in the pursuit of common goals is just as important today as it was in our evolutionary past. If that ability can be developed and enhanced, as research strongly suggests, educational research and practice should be concerned with its development per se, and not only with collaboration as a pedagogic device for individual tuition. We commonly hear today of the need for "good team players"—and that does not just mean being amiable colleagues. It is in the interests of society that children are taught how to become effective interthinkers.

The explanatory framework I have used, sociocultural theory, does not avoid or deny recognition of the role of the individual in "making sense" but examines that role in the context of processes of collective thinking activity and the creation of socially shared knowledge. In an earlier issue of this journal, Säljö (2009) suggested that "the point of a theory does not lie in its correspondence with the world (which would be the realist perspective) but rather in its explanatory power in relation to a set of issues" (p. 204). My interest in the social brain and collective thinking has a strong practical dimension. I want to know why some teachers are better than others at helping their students achieve higher levels of attainment, how levels of attainment are related to features of children's social and communicative experience, and why and how group-work promotes learning. I also want to know how best to educate children as "interthinkers." Research has shown that the potential of the social brain is often being squandered in classroom education, because it is not being used, or educated, effectively. We know that collaborative learning benefits individual learning, but only under certain conditions. We are now able to identify the pedagogic strategies that can maximize the educational impact of classroom interactions and to develop children's skills in reasoning collectively. We need to ensure that children gain most benefit from collaborative learning, and enable them to take part productively in the collective thinking activities of the wider world. More educational benefit would be likely to come from this than from the pursuit of such popular "neuromyths" as "learning styles," "right/left laterality," and "whole-brain learning" (as discussed by Goswami, 2007). In summary, then, I hope that I have provided good reasons for psychologists of education to adopt, adapt, and develop the concept of the social brain. In doing so, and making links with colleagues in other branches of psychology, the outcome might be a better and more useful understanding of the distinctive nature and origins of human cognition.

ACKNOWLEDGMENTS

Thanks to Clark Chinn, Lyn Dawes, Usha Goswami, Christine Howe, Karen Littleton, Bert van Oers, Deborah Pino-Pasternak, David Whitebread, and three anonymous reviewers for very constructive comments on drafts of this article.

REFERENCES

Abrams, D. A., Nicol, T., Zecker, S., & Kraus, N. (2008). Right hemisphere auditory cortex is dominant for coding syllable patterns in speech. *Journal of Neuroscience*, *28*, 3958–3965. doi:10.1523/JNEUROSCI.0187-08.2008

Downloaded by [University of Cambridge] at 01:34 24 June 2013

Alexander, R. J. (2001). *Culture and pedagogy: International comparisons in primary education* (pp. 391–528). Oxford, UK: Blackwell.

Alexander, R. (2008). Culture, dialogue and learning: Notes on an emerging pedagogy. In N. Mercer & S. Hodgkinson (Eds.), *Exploring talk in schools* (pp. 91–114). London, UK: Sage.

Augustinova, M. (2008) Falsification cueing in collective reasoning: Example of the Wason selection task. *European Journal of Social Psychology*, *38*, 770–785. doi:10.1002/ejsp.532

Baker, C. (2006) *Foundations of bilingual education and bilingualism*. Clevedon, UK: Multilingual Matters.

Bakhtin, M. (1981). *The dialogic imagination*. Austin: University of Texas Press.

Barnes, D. (1976). *From communication to curriculum*. Harmondsworth, UK: Penguin.

Barnes, D. (2008). Exploratory talk for learning. In N. Mercer & S. Hodgkinson (Eds.), *Exploring talk in school* (pp. 1–16). London, UK: Sage.

Barnes, D. (2010). Why talk is important. *English Teaching: Practice and Critique*, *9*, 7–10.

Barton, D. (2009). Understanding textual practices in a changing world. In M. Baynham & M. Prinsloo (Eds.), *The future of literacy studies* (pp. 38–53). Basingstoke, UK: Palgrave Macmillan.

Bennett, N., & Cass, A. (1989). The effects of group composition on group interactive processes and pupil understanding. *British Educational Research Journal*, *15*, 119–132. doi:10.1080/0141192890150102

Berkowitz, M., Gibbs, J., & Broughton, J. (1980). The relation of moral judgement stage disparity to developmental effects of peer dialogues. *Merrill-Palmer Quarterly*, *26*, 341–357.

Bialystok, E., Craik, F., Grady, C., Chau, W., Ishii, R., Gunji, A., & Pantev, C. (2005). Effect of bilingualism on cognitive control in the Simon task: Evidence from MEG. *NeuroImage*, *24*, 40–49. doi:10.1016/j.neuroimage.2004.09.044

Bialystok, E., & Feng, X. (2010). Language proficiency and its implications for monolingual and bilingual children. In A. Durgunoglu & C. Goldenberg (Eds.). *Dual language learners: The development and assessment of oral and written language* (pp. 121–138). New York, NY: Guilford.

Black, P. (2009) Looking again at formative assessment. *Learning and Teaching Update*, *30*, 3–5.

Black, P., & Wiliam, D. (1998). *Inside the black box: Raising standards through classroom assessment*. London, UK: Kings College School of Education.

Bruner, J. S. (1983). *Child's talk: Learning to use language*. Oxford, UK: Oxford University Press.

Buss, D. (2001). Human nature and culture: an evolutionary psychology perspective. *Journal of Personality*, *69*, 955–978. doi:10.1177/026565908500100113

Cazden, C. (2001). *Classroom discourse: The language of teaching and learning* (2nd ed.). New York, NY: Heinemann.

Chartrand, T. L., & Bargh, J. A. (1999). The chameleon effect: The perception–behavior link and social interaction. *Journal of Personality and Social Psychology*, *76*, 893–910. doi:10.1037//0022-3514.76.6.893

Chinn, C., Anderson, R., & Waggoner, M. (2001). Patterns of discourse in two kinds of literature discussion. *Reading Research Quarterly*, *36*, 378–411. doi:10.1598/RRQ.36.4.3

Christie, F., & Martin, J. (1997). *Genre and institutions: Social processes in the workplace and school*. London, UK: Cassell.

Clark, A. (1998). Magic words: How language augments human computation. In P. Carruthers & J. Boucher (Eds.), *Language and thought: Interdisciplinary themes* (pp. 162–183). Cambridge, UK: Cambridge University Press.

Daniels, H. (2001). *Vygotsky and pedagogy*. London, UK: Routledge/Falmer.

Daniels, H. (2008). *Vygotsky and research*. Abingdon, UK: Routledge.

Darcy, N. (1963). Bilingualism and the measurement of intelligence: Review of a decade of research. *Journal of Genetic Psychology*, *103*, 259–282. doi:10.1080/00221325.1963.10532521

Dawes, L. (2008). Encouraging students' contribution to dialogue during science. *School Science Review*, *90*, 101–107.

Dawes, L. (2012). *Talking points: Discussion activities in the primary classroom*. London, UK: David Fulton.

Dawkins, R. (1976). *The selfish gene*. Oxford, UK: Oxford University Press.

Diaz, R. (1983). Thought and two languages: The impact of bilingualism on cognitive development. *Review of Research in Education*, *10*, 23–54. doi:10.2307/1167134

Dignath, G., Buettner, G., & Langfeldt, H-P. (2008). How can primary school students learn self-regulated learning strategies most effectively? A meta-analysis on self-regulation training programmes. *Educational Research Review*, *3*, 101–129.

Dunbar, R. (1998). The social brain hypothesis. *Evolutionary Anthropology*, *6*, 178–189.

Edwards, D., & Mercer, N. (2012). *Common knowledge: The development of understanding in the classroom*. London, UK: Methuen/Routledge. (Original work published 1987)

Edwards, D., & Middleton, D. (1986). Joint remembering: Constructing an account of shared experience through conversational discourse, *Discourse Processes*, *9*, 423–459. doi:10.1080/01638538609544651

Elbers, E. (1994). Sociogenesis and children's pretend play: A variation on Vygotskian themes. In W. de Graaf & R. Maier (Eds.), *Sociogenesis re-examined* (pp. 58–72). New York, NY: Springer. doi:10.1007/978-1-4612-2654-3_13

Fidalgo, Z., & Pereira, F. (2005). Sociocultural differences and the adjustment of mothers' speech to their children' cognitive and language comprehension skills. *Learning and Instruction*, *15*, 1–21.

Fiedler, K., & Bless, H. (2001). Social cognition. In M. Hewstone & W. Stroebe (Eds.), *Introduction to social psychology* (pp. 123–146). London, UK: Sage.

Forman, E. A., & Cazden, C. B. (1985). Exploring Vygotskian perspectives in education: the cognitive value of peer interaction. In J. V. Wertsch (Ed.), *Culture, communication and cognition: Vygotskian perspectives* (pp. 323–347). Cambridge, UK: Cambridge University Press.

Frith, C., & Singer, T. (2008). The role of social cognition in decision making. *Philosophical Transactions of the Royal Society*, *363*, 3875–3886. doi:10.1098/rstb.2008.0156

Goodman, S. (1996). Market forces speak English. In S. Goodman & D. Graddol (Eds.), *Redesigning English: New texts, new identities* (pp. 141–163). London, UK: Routledge.

Goswami, U. (2007). Neuroscience and education: From research to practice. *Nature Review Neuroscience*, *7*, 406–413. doi:10.1038/nrn1907

Goswami, U. (2009). Mind, brain, and literacy-biomarkers as usable knowledge for education. *Mind, Brain, and Education*, *3*, 176–184. doi:10.1111/j.1751-228X.2009.01068.x

Grist, M. (2009). *Changing the subject: How new ways of thinking about human behavior might change politics, policy and practice*. London, UK: Royal Society of Arts. Retrieved from http://www.thersa.org/_data/assets/pdf_file/0020/250625/Nov28th2009ChangingThe-Subject Pamphlet.pdf

Grosjean, F. (2010). *Bilingual: Life and reality*. Cambridge, MA: Harvard University Press.

Hämäläinen, R., & Vähäsantane, K. (2011). Theoretical and pedagogical perspectives on orchestrating creativity and collaborative learning. *Educational Research Review*, *6*, 169–184. doi:10.1016/j.edurev.2011.08.001

Hart, B., & Risley, T. R. (1995). *Meaningful differences in the everyday experience of young American children*. New York, NY: Brookes.

Hattie, J. A., Biggs, J., & Purdie, N. (1996). Effects of learning skills interventions on student learning: a meta-analysis. *Review of Educational Research*, *66*, 99–136. doi:10.2307/1170605

Hermann, E., Call, J., Hernandez-Lloreda, M. V., Hare, B., & Tomasello, M. (2007). Humans have evolved specialized skills of social cognition: The cultural intelligence hypothesis. *Science*, *317*, 1360. doi:10.1126/science.1146282

Downloaded by [University of Cambridge] at 01:34 24 June 2013

Heyes, C. M. (2010). Where do mirror neurons come from? *Neuroscience and Biobehavioural Reviews*, *34*, 575–583. doi:10.1016/j.neubiorev.2009.11.007

Howe, C. (2009). Collaborative group work in middle childhood: Joint construction, unresolved contradiction and the growth of knowledge. *Human Development*, *52*, 215–219.

Howe, C. (2010). *Peer groups and children's development*. Oxford, UK: Wiley-Blackwell. doi:10.1002/9781444318098

Iiskala, T., Vauras, M., Lehtinen, E., & Salonen, P. (2011). Socially shared metacognition of dyads of pupils in collaborative mathematical problem-solving processes. *Learning and Instruction*, *21*, 379–393. doi:10.1016/j.learninstruc.2010.05.002

Janis, I. (1982). *Groupthink: Psychological studies of policy decisions and fiascoes*. New York, NY: Houghton Mifflin.

Jeong, H., & Chi, M. (2007). Knowledge convergence and collaborative learning. *Instructional Science*, *35*, 287–315. doi:10.1007/s11251-006-9008-z

Jewitt, C. (2008). *Technology, literacy, learning: A multimodality approach*. London, UK: Routledge.

Jewitt, C., Kress, G., Ogborn, J., & Tsartsarelis, C. (2004). Exploring learning through visual, actional and linguistic communication: The multimodal environment of science classroom. *Educational Review*, *53*, 6–16. doi:10.1080/00131910120033600

John-Steiner, V. (2000). *Creative collaboration.* New York, NY: Oxford University Press.

Karmiloff-Smith, A. (1979). Problem solving construction and representation of closed railway circuits. *Archives of Psychology*, *47*, 37–59.

Keefer, M., Zeitz, C., & Resnick, L. (2000). Judging the quality of peer-led student dialogues. *Cognition and Instruction*, *18*, 53–81. doi:10.1207/S1532690XCI1801_03

Kress, G. (1987). Genre in a social theory of language. In I. Reid (Ed.), *The place of genre in learning* (pp. 33–43). Geelong, Australia: Deakin University Press. doi:10.1111/j.1754-8845.1992.tb01061.x

Larkin, S. (2009). Socially mediated metacognition and learning to write. *Thinking Skills and Creativity*, *4*, 149–159. doi:10.1016/j.tsc.2009.09.003

Laughlin, P. R., Hatch, E. C., Silver, J. S., & Boh, L. (2006). Groups perform better than the best individuals on letters-to-numbers problems: Effects of group size. *Journal of Personality and Social Psychology*, *90*, 644–651. doi:10.1037/0022-3514.90.4.644

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press. doi:10.1017/CBO9780511815355

Leat, D., & Lin, M. (2003). Developing a pedagogy of metacognition and transfer: some signposts for the generation and use of knowledge and the creation of research partnerships. *British Educational Research Journal*, *29*, 383–416. doi:10.1080/01411920301853

Lemke, J. L. (1990). *Talking science: Language, learning and values*. Norwood, MA: Ablex.

Levinson, S. C. (2006). On the human "interaction engine." In N. J. Enfield, & S. C. Levinson (Eds.), *Roots of human sociality: Culture, cognition and interaction* (pp. 39–69). Oxford, UK: Berg.

Littleton, K., & Mercer, N. (2013). *Interthinking: Putting talk to work*. Abingdon, UK: Routledge.

Macnamara, J. (1966). *Bilingualism and primary education*. Edinburgh, UK: Edinburgh University Press.

Martin, J. (1993). Genre and literacy: Modeling context in educational linguistics. *Annual Review of Applied Linguistics*, *13*, 141–172. doi:10.1017/S0267190500002440

Mason, L. (2009). Bridging neuroscience and education: A two-way path is possible. *Cortex*, *45*, 548–549. doi:10.1016/j.cortex.2008.06.003

Maybin, J. (2006). *Children's voices: Talk, knowledge and identity*. Basingstoke, UK: Palgrave Macmillan.

Mercer, N. (1995). *The guided construction of knowledge: talk amongst teachers and learners*. Clevedon, UK: Multilingual Matters.

Mercer, N. (2000). *Words and minds: How we use language to think together.* London, UK: Routledge. doi:10.4324/9780203464984

Mercer, N. (2008). The seeds of time: Why classroom dialogue needs a temporal analysis. *Journal of the Learning Sciences*, *17*, 33–59. doi:10.1080/10508400701793182

Mercer, N. (2009). The analysis of classroom talk: Methods and methodologies. *British Journal of Educational Psychology*, *80*, 1–14. doi:10.1348/000709909X479853

Mercer, N., Dawes, R., Wegerif, R., & Sams, C. (2004). Reasoning as a scientist: Ways of helping children to use language to learn science. *British Educational Research Journal*, *30*, 367–385. doi:10.1080/01411920410001689689

Mercer, N., & Littleton, K. (2007). *Dialogue and the development of children's thinking*. London, UK: Routledge

Mercer, N., & Sams, C. (2006). Teaching children how to use language to solve maths problems. *Language and Education*, *20*, 507–527. doi:10.2167/le678.0

Mercier, H., & Sperber, D. (2011). Why do humans reason? Arguments for an argumentative theory. *Behavioral and Brain Sciences*, *34*, 57–74. doi:10.1017/S0140525X10000968

Michaels, S., & O'Connor, M. C. (2002). *Accountable talk: Classroom conversation that works*. Pittsburgh, PA: University of Pittsburgh.

Middleton, D., & Edwards, D. (1990). (Eds.). *Collective remembering*. London, UK: Sage.

Middup, C., Coughlan, T., & Johnson, P. (2010). How creative groups structure tasks through negotiating resources. In M. Lewkowicz, P. Hassanaly, M. Rohde, & V. Wulf (Eds.), *Proceedings of COOP 2010: Computer Supported Cooperative Work* (pp. 203–221). London, UK: Springer-Verlag. doi:10.1007/978-1-84996-211-7_12

Midgely, M. (2010). *The solitary self: Darwin and the selfish gene*. London, UK: Acumen. doi:10.1017/UPO9781844654833

Miell, D., & Littleton, K. (2004). *Collaborative creativity: Contemporary perspectives*. London, UK: Free Association Books.

Miell, D., & Littleton, K. (2008). Musical collaboration outside school: Processes of negotiation in band rehearsals. *International Journal of Educational Research*, *47*, 41–49. doi:10.1016/j.ijer.2007.11.006

Miller, G. F. (1999). Sexual selection for cultural displays. In R. Dunbar, C. Knight, & C. Power (Eds.), *The evolution of culture* (pp. 71–91). Edinburgh, UK: Edinburgh University Press.

Mukamel, R., Ekstrom, A., Kaplan, J., Iacoboni, M., & Fried, I. (2010). Single-neuron responses in humans during execution and observation of actions. *Current Biology*, *20*, 750–756. doi:10.1016/j.cub.2010.02.045

Muller-Mirza, N., & Perret-Clermont, A-N. (2009). *Argumentation and education*. New York, NY: Springer. doi:10.1007/978-0-387-98125-3

Murphy, P., Wilkinson, I., Soter, A., Hennessy, M., & Alexander, J. (2009). Examining the effects of classroom discussion on students' comprehension of text: A meta-analysis. *Journal of Educational Psychology*, *101*, 740–764.

Nemeth, C. J. (1995). Dissent as driving cognition, attitudes, and judgments. *Social Cognition*, *13*, 273–291. doi:10.1521/soco.1995.13.3.273

Nystrand, M. (1997). *Opening dialogue: Understanding the dynamics of language and learning in the English classroom*. New York, NY: Teachers College Press.

Patel, A. D. (2003). Language, music, syntax and the brain. *Nature Neuroscience*, *6*, 674–681.

Paulus, P., Dzindolet, M., & Kohn. N. (2012). Collaborative creativity-group creativity and team innovation. In M. Mumford (Ed.), *The handbook of organizational creativity* (pp. 327–358). London, UK: Academic. doi:10.1016/B978-0-12-374714-3.00014-8

Paulus, P. B., & Nijstad, B. A. (2003). *Group creativity: Innovation through collaboration*. New York, NY: University Press.

Pea, R. (1993). Learning scientific concepts through material and social activities: Conversational analysis meets conceptual change. *Educational Psychologist*, *28*, 265–277. doi:10.1207/s15326985ep2803_6

Piaget, J. (1926). *The language and thought of the child*. New York, NY: Harcourt Brace Jovanovich.

Downloaded by [University of Cambridge] at 01:34 24 June 2013

Pinker, S. (1994). *The language instinct*. London, UK: Penguin.

Pinker, S. (2007). *The stuff of thought: Language as a window into human nature*. London, UK: Penguin.

Premack, D., & Woodruff, G. (1978). Does the chimpanzee have a theory of mind? *Behavioral and Brain Sciences*, *1*, 515–526. doi:10.1017/S0140525X00076512

Raven, J., Court, J., & Raven, J. C. (1995). *Manual for Raven's Progressive Matrices and Vocabulary Scales*. Oxford, UK: Oxford Psychologists Press.

Reese, E., Haden, C. A., & Fivush, R. (1993). Mother–child conversations about the past: Relationships of style and memory over time. *Cognitive Development*, *8*, 403–430. doi:10.1016/S0885-2014(05)80002-4

Reznitskaya, A., Anderson, R., McNurlen, B., Nguyen-Jahiel, K., Archodidou, A., & Kim, S. (2001). Influence of oral discussion on written argument. *Discourse Processes*, *32*, 155–175. doi:11207/S15326950DP3202&3_04

Reznitskaya, A., & Gregory, M. (2013). Student thought and classroom language: Examining the mechanisms of change in dialogic teaching. *Educational Psychologist*, *48*, 114–133. doi:10.1080/00461520.2013.7758958

Rojas-Drummond, S. (2009). Rethinking the role of peer collaboration in enhancing cognitive growth. *Human Development*, *52*, 240–245.

Rojas-Drummond, S., Mazon, N., Fernandez, M., & Wegerif, R. (2006). Explicit reasoning, creativity and co-construction in primary school children's collaborative activities. *Thinking Skills and Creativity*, *1*, 84–94. doi:10.1016/j.tsc.2006.06.001

Rojas-Drummond, S., & Mercer, N. (2004). Scaffolding the development of effective collaboration and learning, *International Journal of Educational Research*, *39*, 99–111. doi:10.1016/S0883-0355(03)00075-2

Rojas-Drummond, S., Mercer, N., & Dabrowski, E. (2001). Teaching-learning strategies and the development of problem solving in Mexican classrooms. *European Journal of Psychology and Education*, *16*, 179–196.

Roseth, C., Johnson, D., & Johnson, R. (2008). Promoting early adolescents' achievement and peer relationships: the effects of cooperative, competitive and individualistic goal structures. *Psychological Bulletin*, *134*, 223–246. doi:10.1037/0033-2909.134.2.223

Royal Society of Arts. (2010). *Royal Society of Arts education seminars: Curriculum and the social brain*. Retrieved from http://www.thersa.org/projects/education/education-seminars-2010/curriculum-and-the-social-brain

Rudek, D., & Haden, C. (2005). Mothers' and preschoolers' mental state language during reminiscing over time. *Merrill-Palmer Quarterly*, *51*, 523–549. doi:10.1037/0033-2909.134.2.223

Säljö, R. (2009). Learning, theories of learning, and units of analysis in research. *Educational Psychologist*, *44*, 202–208. doi:10.1080/00461520903029030

Sawyer, R. K. (2012). *Explaining creativity: The science of human innovation* (2nd ed.). New York, NY: Oxford University Press.

Sawyer, R. K., & DeZutter, S. (2009). Distributed creativity: How collective creations emerge from collaboration. *Journal of Aesthetics, Creativity, and the Arts*, *3*, 81–92. doi:10.1037/a0013282

Schulz-Hardt, S., Brodbeck, F. C., Mojzisch, A., Kerschreiter, R., & Frey, D. (2006). Group decision making in hidden profile situations: Dissent as a facilitator for decision quality. *Journal of Personality and Social Psychology*, *91*, 1080–1093. doi:10.1037/0022-3514.91.6.1080

Scott, P. (2008). Talking a way to understanding in science classrooms. In N. Mercer & S. Hodgkinson (Eds.), *Exploring talk in school* (pp. 17–36). London, UK: Sage.

Sfard, A, (2001). Symbolizing mathematical reality into being: How mathematical discourse and mathematical objects create each other. In P. Cobb, K. E. Yackel, & K. McClain (Eds.), *Symbolizing and communicating: Perspectives on mathematical discourse, tools, and instructional design* (pp. 37–98). Mahwah, NJ: Erlbaum.

Siegler, R. S. (2002). Microgenetic studies of self-explanation. In N. Granott & J. Parziole (Eds.), *Microdevelopment: Transition processes in development and learning*. Cambridge, UK: Cambridge University Press. doi:10.1017/CBO9780511489709.002

Skidmore, D. (2006). Pedagogy and dialogue. *Cambridge Journal of Education*, *36*, 503–514. doi:10.1080/03057640601048407

Slavin, R. E. (2009). Cooperative learning. In G. McCulloch & D. Crook (Eds.), *International encyclopaedia of education* (pp. 161–178). Abington, UK: Routledge.

Slavin, R., Groff, C., & Lake, C. (2009). Effective programs in middle and high school mathematics: A best-evidence synthesis. *Review of Educational Research*, *79*, 839–911. doi:10.3102/0034654308330968

Smith, M. K., Wood, W., Adams, W., Wieman, C., Knight, J., Guild, N., & Su, T. (2009). Why peer discussion improves student performance on in-class concept questions. *Science*, *323*, 122–124. doi:10.1126/science.1165919

Soong, B., & Mercer, N. (2011). Improving students' revision of physics concepts through ICT-based co-construction and prescriptive tutoring. *International Journal of Science Education*, *33*, 1055–1078. doi:10.1080/09500693.2010.489586

Swales, A. (1990). *Genre analysis: English in academic and research settings*. Cambridge, UK: Cambridge University Press.

Swanson, H. L., Hoskyn, M., & Lee, C. (1999). *Intervention for students with learning disabilities: A meta-analysis of treatment outcomes*. New York, NY: Guilford.

Tomasello, M. (2008, May 25). How are humans unique? *The New York Times Magazine*. Retrieved from http://www.nytimes.com/

Treagust, D., & Duit, R. (2008a). Compatibility between cultural studies and conceptual change in science education: There is more to acknowledge than to fight straw men! *Cultural Studies of Science Education*, *3*, 387–395. doi:10.1007/s11422-008-9096-y

Treagust, D., & Duit, R. (2008b). Conceptual change: A discussion of theoretical, methodological and practical challenges for science education. *Cultural Studies of Science Education*, *3*, 297–328. doi:10.1007/s11422-008-9090-4

van Oers, B., Elbers, E., van der Veer, R., & Wardekker, W. (Eds.). (2008). *The transformation of learning: Advances in cultural-historical activity theory*. Cambridge, UK: Cambridge University Press.

Vass, E., & Littleton, K. (2010). Peer collaboration and learning in the classroom. In K. Littleton, C. Wood, & J. Kleine Staarman (Eds.), *International handbook of psychology in education* (pp. 105–136). Leeds, UK: Emerald.

Veenman, M. V. J., & Spaans, M. A. (2005). Relation between intellectual and metacognitive skills: Age and task differences. *Learning and Individual Differences*, *15*, 159–176. doi:10.1016/j.lindif.2004.12.001

Volet, S., Summers, M., & Thurman, J. (2009). High-level co-regulation in collaborative learning: How does it emerge and how is it sustained? *Learning and Instruction*, *19*, 128–143. doi:10.1016/j.learninstruc.2008.03.001

Vygotsky, L. S. (1962). *Thought and language*. Cambridge, MA: MIT Press.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Walshaw, M., & Anthony, G. (2008). The teacher's role in classroom discourse: A review of recent research into mathematics classrooms. *Review of Educational Research*, *78*, 516–551. doi:10.3102/0034654308320292

Wang, M. C., Haertel, G. D., & Walberg, H. J. (1990). What influences learning? A content analysis of review literature. *Journal of Educational Research*, *84*, 30–43.

Warwick, P., Mercer, N., Kershner, R., & Kleine Staarman, J. (2010). In the mind and in the technology: The vicarious presence of the teacher in pupil's learning. *Computers and Education*, *55*, 350–362. doi:10.1016/j.compedu.2010.02.001

Webb, N., Nemer, K., & Ing, M. (2006). Small-group reflections: Parallels between teacher discourse and student behavior in peer-directed groups. *Journal of the Learning Sciences*, *15*, 63–119. doi:10.1207/s15327809jls1501_8

Wegerif, R. (2007). *Dialogic education and technology: Expanding the space of learning*. New York, NY: Springer.

Wegerif, R. (2010). *Mindexpanding: Teaching for thinking and creativity in primary education*. Maidenhead, UK: Open University Press/McGraw Hill.

Wegerif, R., & Scrimshaw, P. (Eds.). (1997). *Computers and talk in the primary classroom*. Clevedon, UK: Multilingual Matters.

Wells, G. (1986). *The meaning makers: Children learning language and using language to learn*. London, UK: Hodder & Stoughton.

Wells, G. (1999). *Dialogic inquiry: Toward a sociocultural practice and theory of education*. Cambridge, UK: Cambridge University Press. doi:10.1017/CBO9780511605895

Wells, G. (2008). Learning to use scientific concepts. *Cultural Studies of Science Education*, *3*, 329–350. doi:10.1007/s11422-008-9100-6

Wells, G. (2009). *The meaning makers: Learning to talk and learning to learn* (2nd ed.). Bristol, UK: Multilingual Matters.

Wertsch, J. V. (1979). From social interaction to higher psychological processes: a clarification and application of Vygotsky's theory. *Human Development*, *22*, 1–22. doi:10.1159/000272425

Whitebread, D., & Pino Pasternak, D. (2010). Metacognition, self-regulation & meta-knowing. In K. Littleton, C. Wood, & J. Kleine Staarman (Eds.), *International handbook of psychology in education* (pp. 615–713). Leeds, UK: Emerald.

Willingham, D. (2009). Three problems in the marriage of science and education. *Cortex*, *45*, 544–545.

Wolpert, D., & Frith, C. (2004). *The neuroscience of social interactions: Decoding, influencing, and imitating the actions of others*. Oxford, UK: Oxford University Press.

Woolley, A., Chabrsi, C., Pentland, A., Hashmi, N., & Malone, T. (2010). Evidence for a collective intelligence factor in the performance of human groups. *Science*, *330*, 686–688. doi:10.1126/science.1193147

Zelazo, P., Chandler, M., & Crone, E. (Eds.). (2009). *Developmental social cognitive neuroscience*. New York, NY: Psychology Press. doi:10.1111/j.1750-8606.2012.00241.x

Downloaded by [University of Cambridge] at 01:34 24 June 2013